

ElectroSpark Deposited Coatings for Replacement of Chrome Electroplating

(SERDP Project 1147)

HCAT Meeting – 2 April 2003

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ELECTROSPARK DEPOSITION (ESD)

Process Summary

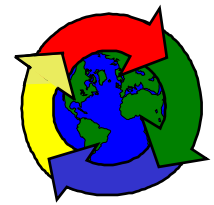
A micro-welding process that uses short-duration, high-current electrical pulses to deposit an electrode material on a metallic substrate. Coating is fused (true metallurgical bond) to substrate with such a low total heat input that the bulk substrate material remains at or near ambient temperature.

Rapid solidification produces nano-structures with unique tribological and corrosion performances.

Coatings of nearly any electrically conductive metal, alloy, or cermet can be applied to metal or cermet substrates.

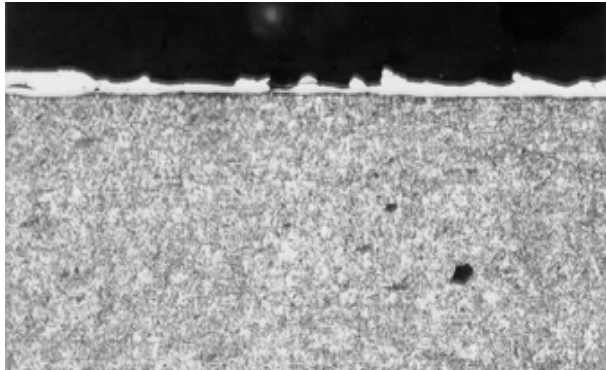


- 1. Selection of candidate coating materials completed.**
- 2. Selection of substrate materials representative of Tri-Service needs completed.**
- 3. Determined effect of wave form on coating quality.**
- 4. High speed videography trials completed, characterization technique eliminated.**
- 5. Completed Taguchi matrices, established electrode contact force as parameter most important for NLOS control.**
- 6. Real-time analysis of pulse wave form used to provide feedback to electronic force controls (patents in progress).**
- 7. Force indicator for manual deposits completed.**
- 8. Characterization of coatings nearing completion (wear and fatigue- preliminary results now available).**

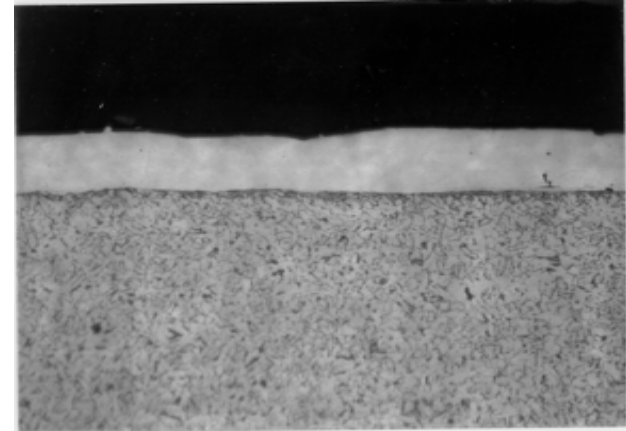


Stellite 6 on 4340 Steel

$30 \mu\text{F}$

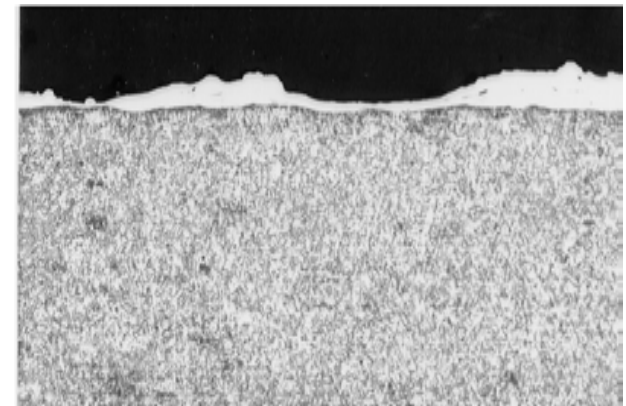
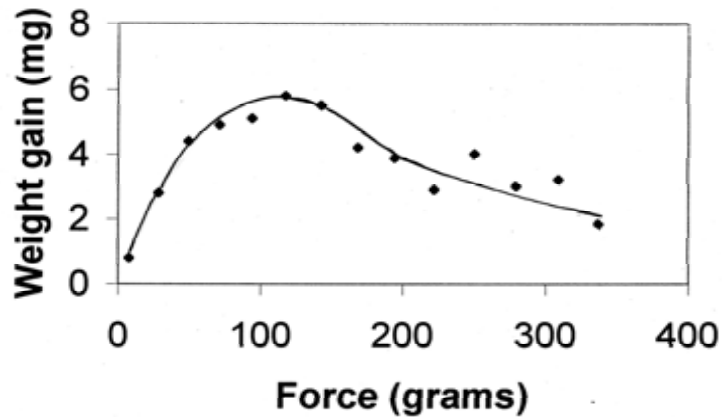


15 g
force



100 g
force

Weight gain vs. contact force



350 g
force

Contact Force Control

Principal Parameter for NLOS Success

- **Phase 1 – Control force in one axis (automated)**

- Hall-effect magnetic switches

- Completed*

- **Phase 2 – Control force in multiple axes (automated)**

- Requires computer analysis of wave form, correlation with force, and feed back to force control module

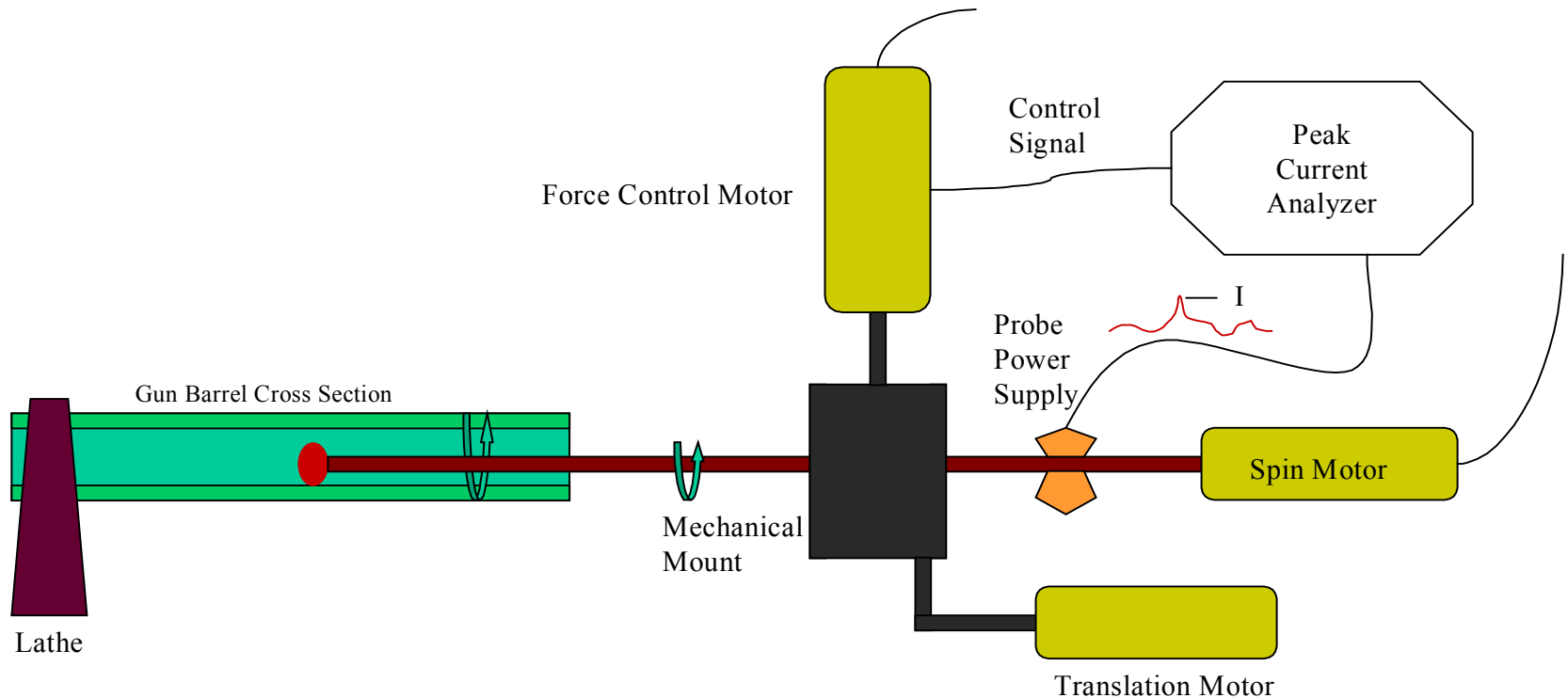
- Completed*

- **Phase 3 – Control force in multiple axes (manual)**

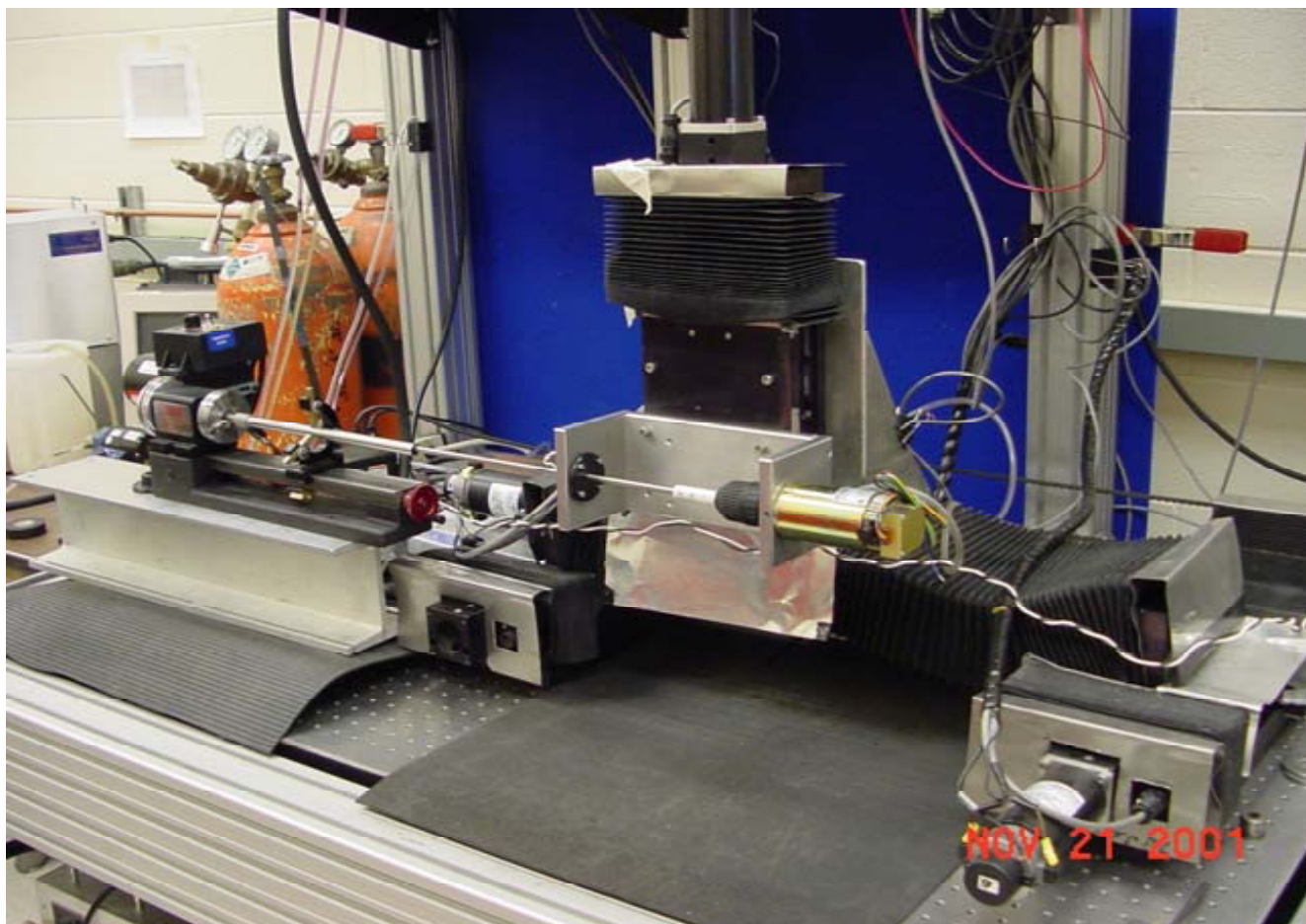
- Computer provides feedback to operator when in optimum range

- Completed*

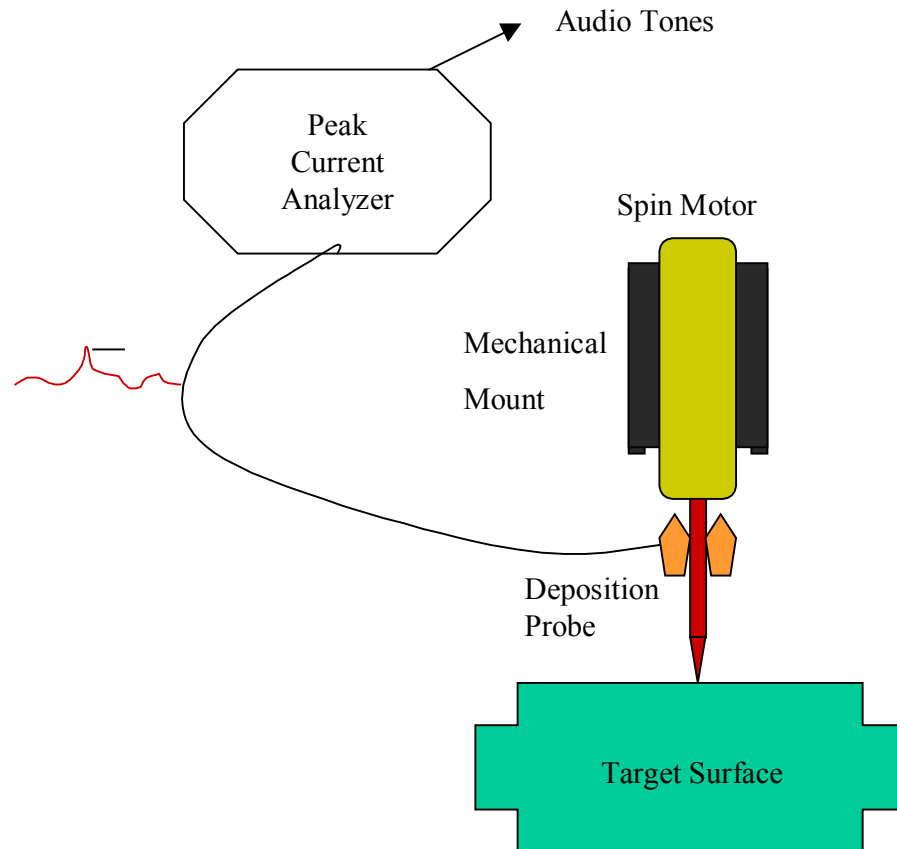
Inside Diameter (Gun Barrel)



Automated ESD Coating of 0.5" Inside Diameter Steel Tube



Hand Held Deposition



Status

- **Real-time analysis** of coating deposition parameters is being done by wave form feedback in non-line-of-sight applications.
- **Electronic controls** have been developed to maintain optimum electrode contact force under varying NLOS conditions (patent application in progress).
- **Force control indicator** for manual applications completed.

Transition Plan

- ESTCP established for technology transition
 - Select candidate components
 - Conduct additional coupon testing specific to component or Tri-Service requirements
 - Coat components for demonstration/validation activities
 - Perform component testing: Rig or lead-the-fleet testing
 - Justify ESD use for DOD applications - perform ECAM
 - Prepare process specifications

Preliminary Wear Results

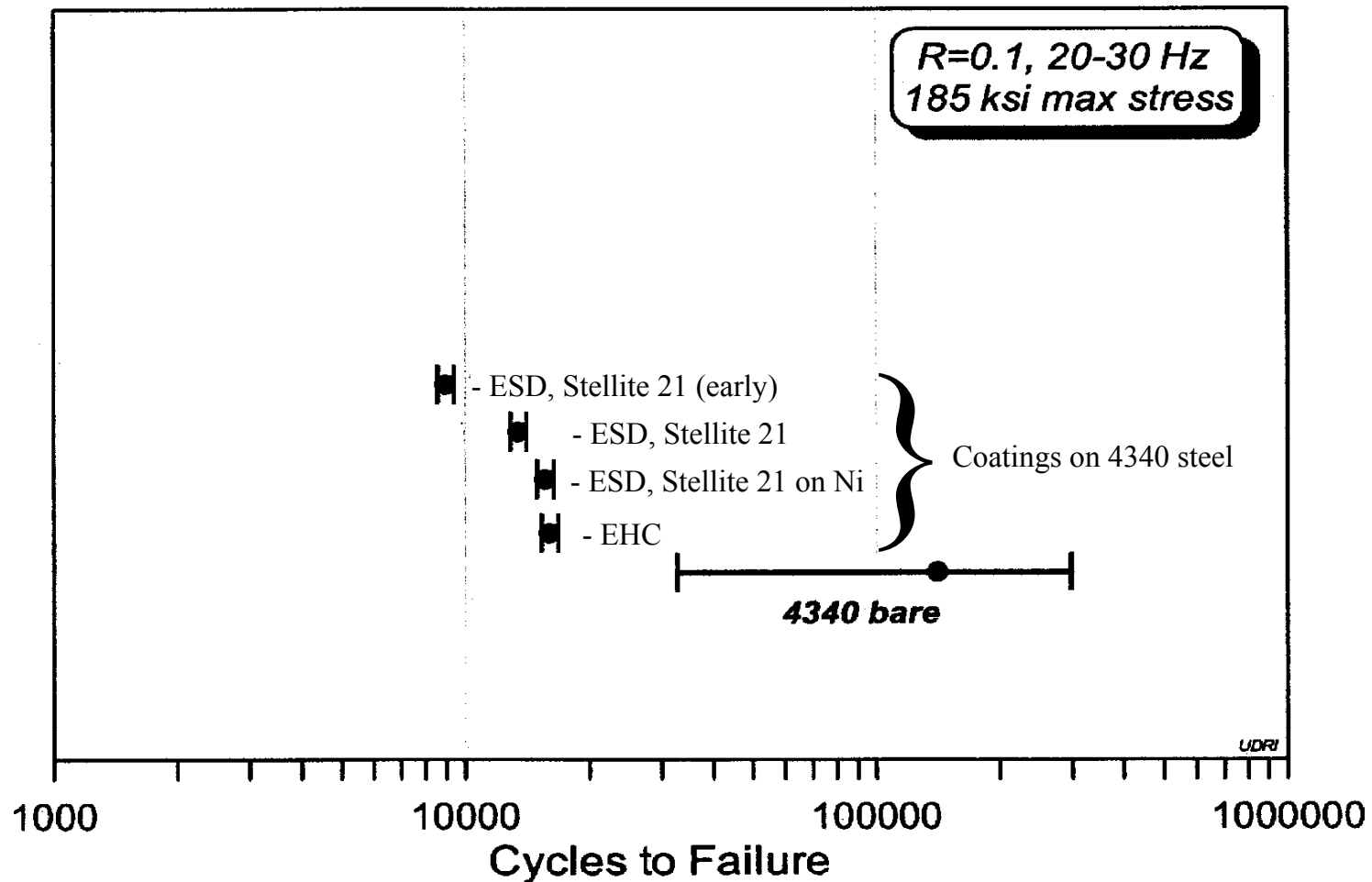
- **Materials** – Stellite 21, Stellite 12, Cr Carbide, TiAl-TiB₂, EHC
- **Test** – Pin-on-Plate, 100 to 500 grams, 440 C pin
- **Wear of Coatings**- Negligible on all except TiAl-TiB₂ (significant wear above 300 grams)
- **Wear of Pin**- $1-4 \times 10^{-11}$ grams (highest pin wear against Stellite 12)

Preliminary Fatigue Tests

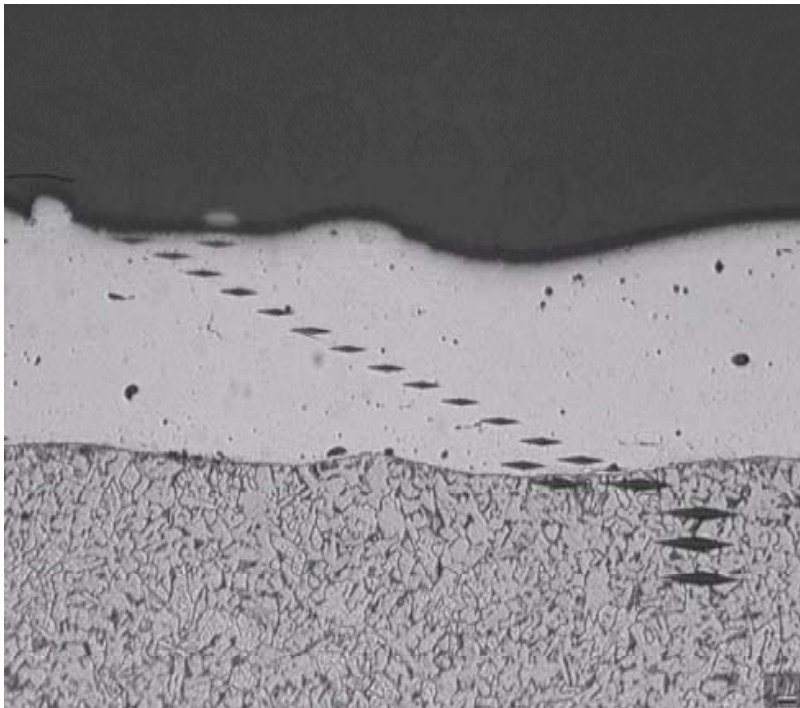
- **Materials** – Stellite 21 on heat treated 4340 steel
- **Test** – 185 ksi, $R = 0.1$, 20 Hz
- **Early results** (non-optimum deposition parameters)
 - Avg. 8965 cycles to failure
- **Later Results** – Stellite 21 only – 13,047 cycles avg.
 - St. 21 over Ni – 15,626 cycles avg.

(for comparison, EHC coating - ~ 18,000 cycles)
- **Additional tests** to be completed

Preliminary Results of Fatigue Testing on ESD Coated 4340 Steel



Nano-structures Enhance Hardness of ESD Coatings



**Hall-Petch effect demonstrated
in hardsurface materials**

Knoop hardness measured on bulk
material and on ESD coating:

<u>Material</u>	<u>Knoop Hardness</u>	
	<u>Bulk</u>	<u>ESD Deposit</u>
Stellite 6	400	700 ± 750
Stellite 21	300	575 ± 600

Repair of Cr Plate by ESD

